

**S-6/PHSH/CC-13/22**

**TDP (Honours) 6th Semester Exam., 2022**

**PHYSICS**

(Honours)

**THIRTEENTH PAPER : (CC-13)**

**Full Marks : 60**

**Time : 3 Hours**

*The figures in the margin indicate full marks.*

**GROUP—A**

**1. Answer any *six* questions :  $2 \times 6 = 12$**

- (a) What is vector potential?
- (b) Show that equation of continuity is contained in Maxwell's equations.
- (c) What is skin effect?
- (d) An electromagnetic wave polarized perpendicular to the plane of incidence impinges at  $30^\circ$  on a glass slab having refractive index 1.5. Find the Fresnel's transmission coefficient.
- (e) What do you mean by uniaxial and biaxial crystals?
- (f) What is double refraction phenomenon?
- (g) State the Biot's law of rotatory polarization.
- (h) Mention two advantages of optical fibres over coaxial cables.

( 2 )

**GROUP—B**

(There are **four** questions from Question No. 2 to Question No. 5. Answer *either (a) or (b)* from each question.)

2. (a) (i) What is Lorentz gauge condition? Is the set of potentials satisfying Lorentz gauge condition unique? Explain.
- (ii) Show that electromagnetic waves in free space, energy is equally shared between electric and magnetic fields.
- (iii) The electric field associated with an electromagnetic wave in free space is given by  $\vec{E} = \hat{x} E_0 \cos(kz - \omega t)$ . Find the corresponding  $\vec{H}$ -field.
- (iv) What is momentum density?

(2+2)+3+3+2=12

( OR )

- (b) (i) State and prove Poynting's theorem. Express the theorem in differential form.
- (ii) Starting from Maxwell's equation, show that in a homogeneous isotropic dielectric medium of permittivity  $\epsilon$  and permeability  $\mu$ , electric and magnetic fields are in phase.



( 3 )

- (iii) Show that in a harmonically varying electromagnetic field represented by complex notations the time average Poynting vector can be represented by

real part of  $\frac{1}{2} \left( \vec{E} \times \vec{H}^* \right)$ , where  $\vec{H}^*$  is the complex conjugate of  $\vec{H}$ .

(1+4+1)+3+3=12

3. (a) (i) A plane electromagnetic wave falls obliquely on the interface between two simple dielectrics. Assuming the electric vector to be parallel to the plane of incidence, obtain expressions for amplitude reflection and transmission coefficients.

- (ii) Show that Brewster's law is a direct consequence of Fresnel's law of reflection.

- (iii) Show that for a good conductor skin depth  $\delta = \frac{\lambda_e}{2\pi}$ , where  $\lambda_e$  is the wavelength of electromagnetic waves in the conductor.

5+4+3=12

( OR )

( 4 )

(b) (i) Show that the phase difference between  $\vec{E}$  and  $\vec{H}$  fields of electromagnetic wave in a perfect conductor is  $45^\circ$ .

(ii) Starting with the equation of motion for electrons in a radiation field, show how the refractive index depends on the frequency. Hence, derive the Cauchy relation of normal dispersion.

(iii) Find the frequency at which skin depth of a seawater is 1m. For sea water, take  $\mu = \mu_0$  and  $\sigma = 4.3 \text{ mho/m}$ .

$$+(4+2)+2=12$$

4. (a) (i) Explain how a Nicol prism can be used to analyse plane polarised light.

(ii) How are elliptically and circularly polarised lights produced experimentally?

(iii) Calculate the thickness of a half-wave plate for sodium light, given  $n_0 = 1.54$  and the ratio of the velocities of O-component and E-component is 1.007. Is the crystal positive or negative? Given, the wavelength of sodium light is  $5893 \text{ \AA}$ .

$$3+(2\frac{1}{2}+2\frac{1}{2})+(3+1)=12$$

( OR )



( 5 )

- (b) (i) If  $n_o$  is the refractive index of O-rays,  $n_e$  is the principal refractive index for E-rays, then, show that the refractive index  $n_\theta$  for E-rays in a direction  $\theta$  with optic axis given by

$$\frac{1}{n_\theta^2} = \frac{\cos^2 \theta}{n_o^2} + \frac{\sin^2 \theta}{n_e^2}$$

- (ii) Describe the construction and working of a Babinet compensator. What is its advantage over quarter or half wave plate?

- (iii) What do you mean by positive crystal and negative crystal?  $4+(4+2)+2=12$

5. (a) (i) Show that a linear vibration may be considered to be equivalent to two oppositely directed circular vibrations.
- (ii) What is rotatory polarisation? Give the Fresnel's theory of optical rotation.
- (iii) A length of 10 cm of a 5% solution causes an optical rotation of  $20^\circ$ . How much length of 10% solution of the same substance will cause a rotation of  $35^\circ$ ?  $3+(2+4)+3=12$

( OR )

( 6 )

- (b) (i) Consider the propagation of electromagnetic waves between two parallel perfectly conducting plates. Considering TE-mode, show that

$$\frac{1}{\lambda_0^2} = \frac{1}{\lambda_g^2} + \frac{1}{\lambda_c^2} \text{ where, } \lambda_g \text{ is the guided wavelength, } \lambda_0 \text{ is the free space wavelength and } \lambda_c \text{ is the cut-off wavelength.}$$

- (ii) What do you mean by a graded index fibre? Discuss its advantages over a step index fibre.

- (iii) For a step index fibre,  $n_1 = 1.5$  and  $\Delta n = 0.015$ . Calculate  $n_2$ , the numerical aperture and the maximum acceptance angle.  $5+(2+2)+3=12$

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**S-6/PHSH/CC-14/22**

**TDP (Honours) 6th Semester Exam., 2022**

**PHYSICS**

(Honours)

**FOURTEENTH PAPER : (CC-14)**

**Full Marks : 60**

**Time : 3 Hours**

*The figures in the margin indicate full marks.*

**GROUP—A**

**1. Answer any ~~six~~ questions :  $2 \times 6 = 12$**

- (a) Write the Planck's quantum hypothesis.
- (b) Write the Kirchhoff law in relation with the black-body radiation.
- (c) Define 'ensemble'.
- (d) What is phase space?
- (e) What is occupation index?
- (f) What do you mean by Fermi-Dirac statistics?
- (g) Define photon gas.
- (h) What is phase space? Write one of its importance.

( 2 )  
**GROUP—B**

There are **four** questions from Question No. 2 to Question No. 5. Answer *either (a) or (b)* of each question.

2. (a) (i) How do you find the temperature of the Sun from the knowledge of solar constant and Stefan's law?
- (ii) What is Stefan's law? Give thermodynamic proof of Stefan's law.
- (iii) How can we derive the Wien's displacement law from Planck's law.

4+5+3=12

( OR )

- (b) (i) What is the spectral distribution of black-body radiation.
- (ii) Obtain Stefan's law of radiation from Planck's law, given that

$$\int_0^{\infty} x^3 e^{-ax} dx = \frac{6}{a^4}$$

- (iii) Derive the Planck's law of black-body radiation.

2+5+5=12



( 3 )

3. (a) (i) Set a relation between the thermodynamic probability and entropy.
- (ii) Derive the expression for the Maxwell Boltzmann distribution law.
- (iii) Write the importance of partition function.  $5+5+2=12$

( OR )

- (b) (i) Define the physical significance of entropy. Why Gibbs paradox is called a paradox? Explain how the paradox was resolved.
- (ii) State the law of equipartition of energy and prove this.
- (iii) Give the basic concept of 'ensemble'. What are the different types of ensemble.  $(1+2+2)+(1+3)+(2+1)=12$
4. (a) (i) Explain the need of introducing the quantum statistics.
- (ii) Five bosons are distributed in two compartments, the first compartment is having 3-cell and the second 4. Find the thermodynamic probability for the macrostate (5,0).

( 4 )

- (iii) What is Bose-Einstein condensation? When is a Bose gas said to be strongly degenerate? Calculate the energy of Bose-Einstein gas.  $2+3+(2+2+3)=12$

( OR )

- (b) (i) Write the basic assumptions of Bose-Einstein quantum statistics.

- (ii) Derive the expression

$$n_i = \frac{g_i}{e^{(\alpha + E_i)/kT} - 1}$$

(The symbols have their usual meanings)

- (iii) Find the number of ways in which 3 bosons may be distributed in four-cell. Write the properties of liquid helium.  $2+5+3+2=12$

5. (a) (i) Starting from Fermi-Dirac distribution law, derive the expression for energy distribution of free electrons in metal.

- (ii) When is Fermi gas said to be non-degenerate? In the limit  $T \rightarrow 0$ , find the mean occupation number of the single particle state.



( 5 )

- (iii) Show that  $\langle n_{\epsilon} \rangle$  is a step function corresponding to the term  $T=0$   
5+2+3+2=12

( OR )

- (b) (i) Using the expression for FD law of distribution of energy among electrons within a metal, prove that at  $0^{\circ}\text{K}$  —  
(1) the average kinetic energy

$$\bar{u} = \frac{3}{5} u_f;$$

- (2) the average velocity  $\bar{v} = \frac{3}{4} v_f,$

$u_f \rightarrow$  the Fermi energy.

$v_f \rightarrow$  The velocity of the electrons at the Fermi energy.

- (ii) Compare the distribution laws for MB, BE and FD statistics. Under what condition do the Bose-Einstein and Fermi-Dirac statistics yield classical result?
- (iii) How many ways can one distributes 9 unit of energy among 6 identical particles. What is the difference between identical and undistinguishable particles?

$$(3+2)+(2+2)+(2+1)=12$$

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**S-6/PHSH/DSE-III/22**

**TDP (Honours) 6th Semester Exam., 2022**

**PHYSICS**

(Honours)

THIRD PAPER : DSE-III

Full Marks : 80

Time : 3 Hours

*The figures in the margin indicate full marks.*

**GROUP—A**

1. Answer any **eight** questions :  $2 \times 8 = 16$
- (a) Discuss the superiority of Lagrangian approach over Newtonian approach.
  - (b) What is cyclic co-ordinate? Write one significance.
  - (c) A particle is moving on the surface of a solid sphere. Find the nature of the constraints for the motion.
  - (d) Calculate the period of a second pendulum as measured by an observer moving with a speed of  $0.9c$ .
  - (e) Show how a particle of zero rest mass carries energy.



( 2 )

- (f) A frame of reference is moving with velocity  $0.8c$  along the +ve  $x$  direction, with respect to the another rest frame of reference in which a rod of length 1.5 meter is placed along the  $y$  axis. Find the contracted length of the rod with respect to the moving frame.
- (g) One gram mass is completely transformed into energy. Find the amount of energy will be evolved.
- (h) How in the non-relativistic limit, the relativistic kinetic energy transforms to the classical kinetic energy?
- (i) What do you mean by a stable and unstable equilibrium?
- (j) Write the equation of continuity in case of fluid motion.
- (k) What do you mean by laminar flow?

### GROUP—B

(There are **four** questions from Question No. 2 to Question No. 5. Answer *either (a) or (b)* from each question.)

2. (a) (i) Define generalized momentum and conservative force. Shows that the generalized momentum corresponding to a cyclic co-ordinate remains conserved.

( 3 )

- (ii) Establish Hamiltonian function for a linear harmonic oscillator and set the equation of motion for it.
- (iii) Show by using Poisson bracket, that the transformation defined by  $q = \sqrt{2P} \sin Q$  and  $p = \sqrt{2P} \cos Q$  is canonical i. e.  $[Q, P] = 1$ .
- (iv) Explain holonomic and nonholonomic constraints with two examples of each type.  $(2+3)+4+4+3=16$

( OR )

- (b) (i) Define Poisson Bracket. Then prove that  $[x, y + z] = [x, y] + [x, z]$
- (ii) Set the Lagrange's equation of motion for a conservative system.
- (iii) State D' Alembert's principle. Let  $f$  be a function of many independent variables and their derivatives. Set the Euler-Lagrangian differential equation of motion.
- (iv) Derive the equation of motion of a particle in central force field using Hamiltonian.  $(1+3)+4+(1+4)+3=16$



( 4 )

3. (a) (i) Show that  $x^2 + y^2 + z^2 - c^2 t^2$  is invariant under Lorentz transformation.
- (ii) With a clear space-time diagram, explain space-like and time-like intervals. "When two events are connected by space-like interval, they may be treated simultaneous." Explain.
- (iii) Construct the Lorentz transformation matrix for four dimensional space and identify it is symmetric or not.
- (iv) Explain Doppler effect from the perspective of four-vector.

$$4+(3+1)+4+4=16$$

( OR )

- (b) (i) Show that the three-dimensional volume element  $dx dy dz$  is not invariant under Lorentz transformation while the 4-D volume element is invariant under Lorentz transformation.
- (ii) Two particles each of rest mass  $m$ , collide head on and stick together before collision. The speed of each mass was 0.6 times of the speed of light in free space. Find the mass of the final entity.

( 5 )

(iii) Write the four components of momentum four-vector and hence prove the invariance of  $E^2 - p^2 C^2$ .

(iv) An electron is moving with a speed, such that its kinetic energy is equal to its rest energy. Find the speed of the electron and also discuss about the mass dependence of the result.

$$4+4+4+4=16$$

4. (a) (i) Show that  $C^2 B^2 - E^2$  is invariant under Lorentz transformation.

(ii) Considering the complete set of transformation rules of  $\vec{E}$  and  $\vec{B}$  vector, construct the electromagnetic field tensor. Identify if the tensor is an anti-symmetric or symmetric tensor.

(iii) A Pi meson at rest decays into a muon and a neutrino. Find the momentum of the muon in terms of the rest mass of Pi meson and muon.

(iv) What is a four-vector? Show that the scalar product of two four-vector is invariant under Lorentz transformation.  $4+(4+1)+3+(1+3)=16$



( 6 )

( OR )

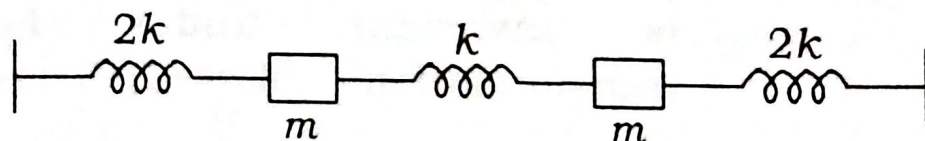
- (b) (i) In case of decay of an unstable particle show that the rest mass of the decaying nucleus is greater than the sum of the rest masses of the resulting components.
- (ii) A photon of energy  $E_0$ , experiences a scattering from an electron at rest. Find the energy  $E$  of the outgoing photon, as a function of the scattering angle.
- (iii) Find the magnetic field of point charge in uniform motion.
- (iv) Write the covariant form of Maxwell's equation. 4+4+4+4=16

5. (a) (i) The potential energy of a particle is given by the expression

$$V(x) = x^4 - 4x^3 - 8x^2 + 48x$$

Find the points of stable and unstable equilibrium.

- (ii) Two blocks of equal masses, each equal to  $m$ , and joined with spring as shown in the figure. They execute small oscillation on a frictionless surface. Find the normal frequencies of oscillator of the system.



( 7 )

- (iii) Two identical harmonic oscillators are coupled together. Set up the equation of motion and find the normal frequencies.
- (iv) Discuss the stationary property of normal mode.  $3+5+5+3=16$

( OR )

- (b) (i) Describe turbulence and streamline motion. What is the physical significance of Reynolds number?
- (ii) Define Navier-Stokes equation.
- (iii) Define rotational and irrotational flows.
- (iv) Derive the equation of continuity and hence explain its importance.  
 $(2+2+1)+5+3+3=16$

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**S-6/PHSH/DSE-IV/22**

**TDP (Honours) 6th Semester Exam., 2022**

**PHYSICS**

(Honours)

**FOURTH PAPER : DSE-IV**

*Full Marks : 80*

*Time : 3 Hours*

*The figures in the margin indicate full marks.*

**GROUP—A**

**1. Answer any **eight** questions :** **2×8=16**

- (a) What do you mean by quantum dot? Give two examples of it.
- (b) What is Coulomb blockade?
- (c) What is sol and what is gel?
- (d) Explain the process of ball milling.
- (e) What do you mean by quasi-particle? Explain with example.
- (f) What do you mean by band offsets in heterojunction?
- (g) What is the difference between resolution and magnification of a microscope?
- (h) What is optical switching?

( 2 )

- (i) Write the differences between photoluminescence and electroluminescence.
- (ii) What do you mean by hopping conductivity?

**GROUP—B**

(There are **four** questions from Question No. 2 to Question No. 5. Answer *either (a) or (b)* from each question.)

2. (a) (i) What do you mean by quantum confinement?
- (ii) How are the DOS (density of states) changed with respect to energy in different dimensional nano-structured materials as a consequences of quantum confinement? Explain with diagram.
- (iii) Write some properties of materials at nanometre size arised when derived from bulk material.
- (iv) What do you mean by aspect ratio? How are the aspect ratio changed in nanomaterials when it is derived from bulk? Explain with suitable example.

2+6+4+4=16

( OR )

- (b) (i) What is a quantum well?



( 3 )

(ii) Write the wave function of first three confined states and energies of the first three confined states of an infinite-depth potential well with schematic diagram.

(iii) Explain the quantum transport in quantum dots.

(iv) Explain with schematic the occurrence of quantum conductance in quantum dot at different bias voltages. Also compare it with current-voltage characteristics of the corresponding bulk systems.  $2+5+3+(3+3)=16$

3. (a) (i) Explain top-down and bottom-up mechanism for synthesis of nanomaterials.

(ii) Write the merits and demerits of top-down and bottom-up techniques.

(iii) Describe the chemical vapour deposition method (CVD) of nanomaterial synthesis.

(iv) Explain how XRD is used for characterisation of nano-structured materials.  $(4+4+4+4)=16$

( 4 )  
( OR )

(b) (i) Write the differences between PVD and CVD.

(ii) Describe the pulsed laser deposition method of nanomaterial synthesis.

(iii) Explain the working theory of AFM technique of nanomaterial characterisation. How is AFM used for characterisation of nano-structured materials.

(iv) Write about different types of Lithography. (3+5+5+3)=16

4. (a) (i) What do you mean by exciton? Discuss how energy band gaps are modified in semiconductor nanocrystals due to exciton.

(ii) Discuss some optical properties of nano-structured materials.

(iii) Write the reasons for change in optical properties of materials at nanoscale.

(iv) What do you mean by band-edge emission and trap state emission related to luminescence spectrum?

(1+4)+4+3+4=16



( 5 )  
( OR )

- (b) (i) Discuss about different types of polarisation arising in dielectric material at nano-scale. Also show the graphically variation of real part of polarisation as a function of frequency.
- (ii) What do you mean by direct and indirect transitions?
- (iii) Describe the relation between the optical properties and the electronic structure of materials. How is it effected as nanoscale?
- (iv) What do you mean by Franz-Keldysh effect?  $(3+2)+3+(3+2)+3=16$
5. (a) (i) Describe how the nanomaterials are used in photonic device like LED and solar cells.
- (ii) Explain how the concept of optical switching is used in optical data storage device.
- (iii) What do you mean by single-electron tunneling phenomenon? Write the differences between single-electron transistor and normal transistor.

( 6 )

- (iv) Write two uses for both of nanostructured thin film and quantum dots.

5+4+4+3=16

( OR )

- (b) (i) What is carbon nanotubes? Discuss about different types of carbon nanotubes.

- (ii) Write and explain four excellent properties of carbon nanotubes.

- (iii) Explain the concept of magnetic quantum well.

- (iv) What do you mean by magnetoresistance? Describe different types of magnetoresistance.

(1+4)+3+3+(1+4)=16

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